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The Propensities and Biomedical Applications of Hydrogels

HuSang Lee

Research Scholars Program, Harvard Student Agencies, In collaboration with Learn with Leaders

ABSTRACT

Hydrogel has been utilized by numerous people due to its unique properties such as various monomers that decide the fundamental properties of the product. These fascinating principles made it possible for the hydrogels to be conspicuous in cosmetic, agricultural, and even pharmaceutical markets.This research is aimed at substantiating the efficacy of hydrogels in varying applications by saliently manifesting the interrelation between the volume and the surrounding medium. This paper provides data of hydrogels with incompatible constituents gathered by Zetasizer machine, and yields an analysis of the consequence. Regarding the rudimentary features of hydrogels, the initial volume of such polymers both altered and fluctuated drastically as inconsistent amounts of monomers and cross-linking agents were amalgamated into hydrogels; this experiment synthesized N-Isopropylacrylamide (NIPA), a common monomer that forms hydrogels, with Sodium Dodecyl Sulfate (SDS), Potassium Persulfate (KPS), Deionized (DI) dihydrogen monoxide, Nitrogen gas, and N, N'-Methylenebisacrylamide (BIS), the cross-linking agent. By adjusting their quantities, it was feasibleto conclude that the quantities are relatively proportional to the volume of hydrogels, meaning that as the amounts of chemicals increased, the diameter of polymers also increased. Furthermore, using different types of cross-linking agents also influenced the resulting volume.The aforementioned results allow the reader to unequivocally visualize the practical use of hydrogels within the multiple systems, and also validate its significance.

Keywords: Hydrogels |Drug Delivery |Medicine | Molecular Chemistry | Bioengineering

Subject: Polymer Chemistry

INTRODUCTION

Hydrogel is three-dimensional, crosslinked polymer that can both swell and shrink as temperature or concentration changes. Among these conditions, there are two major phase transitions that are depended on temperature: thermoswelling and thermoshrinking type.[1]The former type of hydrogels is mainly formed by hydrophilic monomers, such as acrylamide, acrylic acid, and methacrylic acid. On the other hand, the latter type contains hydrophobic monomers, such as N, N-dimethylacrylamide andN-isopropylacrylamide (NDMA and NIPA, respectively). These monomers are mixed with different chemicals to produce hydrogels. One noteworthy characteristic of these gels is that they are highly flexible and biocompatible. Such an astonishing identity of the complex polymers attracted the scientists to research their potential exploitation in everyday life. Surprisingly, numerous products, including contact lenses, wound dressings, diapers, botox, and other biomaterials are produced by hydrogels. This reality makes it evident that hydrogels are widely present in daily products. However, despite their rising studies, commercial products with hydrogels in drug delivery and other biomaterials are still limited due to the lack of research.[2]Specifically, the porous composition (shown in Figure 1) of the polymer upticks an interest of its use within the drug delivery system.[3]

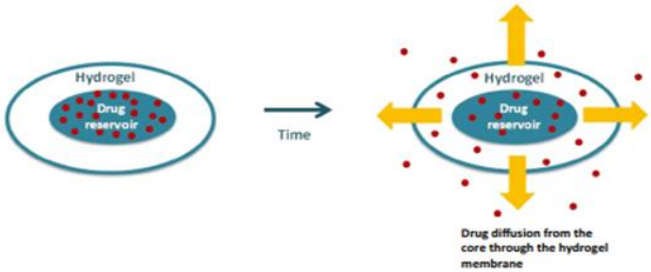

Fig.1 Biomedical applications of hydrogels: A review of patents and commercial products.
Source: Vitaliy& Khutoryanskiy (2014).

The distinctive porosity of hydrogels enables their affinity for insurmountable drugs in an aqueous environment. By modifying the cross-links in the gel, such a porous structure can be tuned so that drugs can be released. One of the remarkable advantages of hydrogels is that it allows the sustained release of medicine inside human body, which leads to drug delivery for a prolonged period of time. It is thus essential to examine whether the theoretical matrix system of hydrogels can be amended when the modification of chemicals is applied. The initial hypothesis of this research was that as the mass cross-linking agents increases, both the volume and the diameter of porosity increases as well, indicating that there would be more space for drugs. These empirical data will not only assist the reader's comprehension, but also expand the research to supplemental applications of bioengineering and others.

MATERIALS AND METHODS

In order to synthesize hydrogels, the following materials are required:N-Isopropylacrylamide, also known as NIPA (*MW* = 113.16 g/mol), provided by Sigma-Aldrich that was used as monomer. Sodium Dodecyl Sulfate, SDS (*MW* = 288.38 g/mol), provided by Sigma-Aldrich was also used lest polymers aggregate intensely during synthesis. Potassium Persulfate, KPS (*MW* = 270.322 g/mol), provided by Sigma-Aldrich was used as an initiator. N, N'-Methylenebisacrylamide, BIS (*MW* = 154.7 g/mol), provided by Sigma-Aldrich was used as a cross-linking agent. Moreover, Tetraethylene Glycol Diacrylate, TEGDA (*MW* = 302 g/mol), provided by Sigma-Aldrich was used as another cross-linking agents. In order to conduct a precise synthesis of hydrogels, distilled water and nitrogen gas within 10.2 liters tank provided by KGS was used for purging.

As a means to keep all the chemicals inside the 100ml of three-necked flask provided by Sigma-Aldrich, condenser provided by Daihan Science was also used. Succeeding the procedure of mixing all the chemicals, octagonal-shaped magnetic stirrer provided by PTFE was placed in the flask. In addition, it is crucial to place the flask on top of an oil bath stirrer provided by AS-One. Next, BCE Analytical Balances provided by Sartorius, pipettes provided by Axygen, several 150ml beakers provided by AS-One, and an injector with syringe filters provided by Sigma-Aldrich were used for more accurate measurements. Lastly, after the synthesis, Zeta Potential Analyzer in the Zetasizer family provided by Malvern Panalytical was used with cuvettes provided by Sigma-Aldrich to measure the particle size of dispersed polymers.

The graph and analysis of the hydrogel's interrelation were accumulated from three distinct experiments supervised. For the first and second experiments, the quantities of BIS got changed. For the third experiment, we used TEGDA instead of BIS to test the consequence of the resulting products when the cross-linking agents are revised. Nevertheless, each experiment shares the identical procedure: First, we weighed 1g of NIPA (monomer), 0.02g of SDS (surfactant), 0.04g of KPS (initiator), 50g of DI water, 0.039g of TEGDA (crosslinker), and 0.02g and 0.042g of BIS (crosslinker) using the analytical balances. Then, we stowed NIPA, SDS, DI water, BIS, magnetic stirrer into the three-necked flask. Subsequently, we placed the flask on the oil bath filled with oil, set the temperature to 80°C and the stirring rate to 200rpm.

Afterwards, it is essential to cover one of the necks of the flask with rubber coverlest the product evaporates, and the rest of the two necks with condenser and pipe that works as a medium for nitrogen gas.After one hour of boiling, mixed the product with KPS (initiator) in order to start the synthesis. We then waited about seven to eight hours until the mixture turned gray. When we poured the synthesized hydrogels in to a beaker, we used an injector encompassed by syringe filter to filtrate the hydrogels and eliminate any leftovers. For the final process of measuring the matrix system of the hydrogels,we used pipette to drop 1mm of the final product into the cuvette. We mixed it with 15mm of DI water. Ultimately, we placed the cuvette into the Zetasizer machine ran the program for five hours to measure the diameter of the polymer three times at each degree level from 50°C to 20°C. When the measurement was completed, we were able to make three graphs after we had conducted two more experiments with 0.042g of BIS and 0.039 of TEGDA.

RESULTS

The results of the experiment came out to be equivalent to the inceptive hypothesis that was made; There are total of three graphswhich represent the varying data recorded by the Zetasizer machine.Throughout the first experiment (shown in Figure 2), the overall fluctuation in diameter of the polymer was 163.5nm, from 111.2nmto 274.7nm. The hydrogel had a dramatic oscillation between 34 °C and 30 °C. During the second experiment (shown in Figure 3), on the other hand, the overall fluctuation in diameter of the hydrogel was 163nm, from 135.2nm to 298.2nm. The hydrogel had a dramatic oscillation between 34 °C and 32 °C. Ultimately, the third and the last experiment with TEGDA (shown in Figure 4) had heterogeneous results from the experiments with BIS; the overall fluctuation in diameter of the hydrogel was 217.9nm, from 186nm to 403.9nm. Nonetheless, the hydrogels with TEGDA also hadsubstantial oscillation between 35 °C and 30 °C.

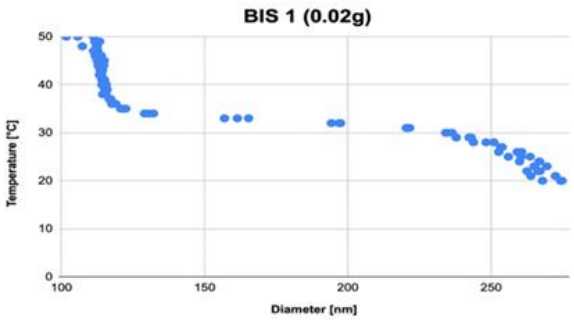

Fig. 2 The graph shows the increase in diameter of thermosensitive hydrogels formed by BIS 1 as temperature fluctuates, during the first experiment.

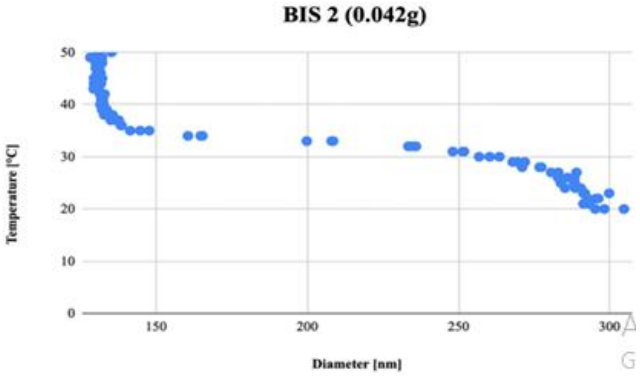

Fig. 3 The graph shows the increase in diameter of thermosensitive hydrogels formed by BIS 2 as temperature fluctuates, during the second experiment.

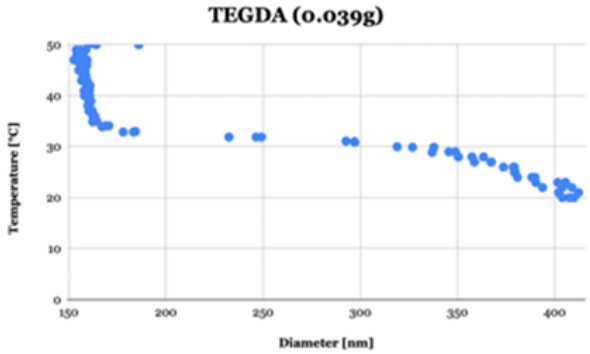

Fig. 4 The graph shows the increase in diameter of thermosensitive hydrogels formed by TEGDA as temperature fluctuates, during the third experiment.

DISCUSSION

One of the most distinguishable findings from this experiment is that all the hydrogels have homogeneous aspect of both expanding and shrinking at certain range of temperature (about 35 °C to30 °C, as demonstrated in the graphs), albeit their data are incongruent. Such a hallmark is highly attributable to the innatematrix system and the porous composition of hydrogels.The overall results were indisputably congruent to the expected results, where the diameter of the polymer would increase when the amount of the cross-linking agents increase, as well as the notion that the diameter will also fluctuate as the consequence of modifying the cross-linking agent itself.

CONCLUSION

Hydrogels have been researched innumerably because of these characteristics. Although one can easily encounter hydrogels in miscellaneous markets, it is unlikely for the hydrogels to appear superficially in pharmaceutical markets. Regardless of the infinite ways of synthesizing billions of chemicals, applying the products right into the drug delivery system or tissue engineering agencies can be substantially controvertible. Hence, at this point of time, it is very crucial to at least unveil the conspicuous ‘propensity’ to the society so that the hydrogel’s efficacy can be eventually substantiated. As shown in the Figure 5, this research was able to visualize one of the proclivities. Further research may explore more about hydrogels by assessing unprecedented monomers and cross-linking agents henceforth.

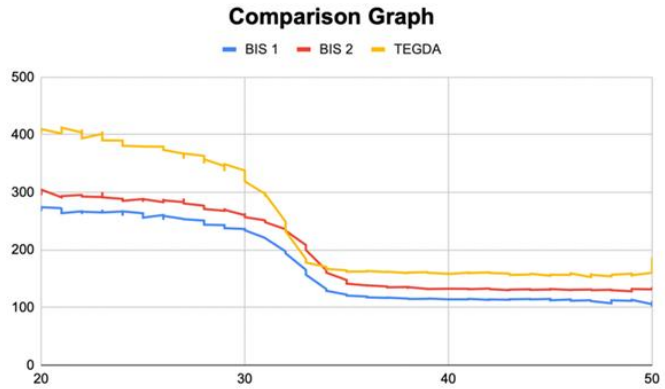

Fig. 5 The three previous graphs are listed in one single graph for better understanding of their gap

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